Abstract

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Autonomous Navigation for Airborne Applications

Autonomous navigation (or localisation) is the process of determining a platform’s pose without the use of any a priori information external to the platform except for what the platform senses about the environment. That is, the determination of the platform’s pose without the use of predefined maps or infrastructure developed for navigation purposes such as terrain aided navigation systems or Global Navigation Satellite System (GNSS). The objective of this thesis is to both develop and demonstrate autonomous localisation algorithms for airborne platforms. The emphasis is placed on the importance of the algorithms to function appropriately and accurately using low cost inertial sensors (where the rapid drift in navigation output requires an increasing reliance on frequent absolute sensing), within an environment where the highly dynamic nature of the platform motion provides unreliable and infrequent absolute sensing. There are five main contributions to this thesis:

Firstly, is the theoretical formulation of the autonomous localisation algorithm for a 6DoF (Degree of Freedom) platform. The process takes on the form of the Simultaneous Localisation and Mapping (SLAM) algorithm which has been quite extensively formulated for the indoor robotics community and for outdoor land vehicle applications. In all these applications though only a 2D problem is posed simplifying the task significantly. By formulating the problem within a 6DoF framework, the SLAM algorithm is now opened to any platform description. In order to develop such a generic model, no absolute platform model can be implemented (which is advantageous) and hence the use of inertial navigation techniques are required in order to allow for prediction of state information, which is developed within this thesis.

Secondly, is the recasting of the SLAM algorithm in order to improve its computational efficiency. SLAM is an expensive process, and more so when the framework calls for 6DoF implementation. Moreover, increasing the number of states which are required to be estimated such as inertial sensor errors, and having the fundamental requirement of high sampling rates when using inertial sensors, further exasperates the problem. To overcome this the algorithm is casted into its error form which
models the error propagation in SLAM, that is, the error propagation of the states and the map. Since, in most cases, the dynamics of the error propagation is significantly slower than the dynamics of the platform itself, then dramatic improvements in computational efficiency take place.

Thirdly, the thesis will add to the already significant research activity in the development of multi-vehicle SLAM, where platforms share map information in order to both improve the quality and the localisation of the platforms. The main focus is not the development of a new algorithm, but the actual implementation of the 6DoF framework within this context.

Fourthly, in order to validate the effectiveness of SLAM, the real-time implementation of the algorithm is developed for a highly dynamic Uninhabited Air Vehicle (UAV). The purpose is to provide a significant engineering contribution towards the knowledge of implementation. The results of the real-time algorithm is compared to an GNSS/Inertial navigation system, to illustrate the validity of the output.

Finally, this thesis also presents a reliable GNSS/Inertial navigation system which couples information from a barometric altimeter. Although not a primary goal (the development was only required to provide a tool to validate the SLAM output), it was found that within highly dynamic environments, low-cost GNSS sensors are vulnerable to outages and long satellite reacquisition times, and hence the INS requires extra aiding, predominately in the form of height information. Furthermore, the real-time implementation of the GNSS/Inertial navigation system is also presented, forming another main engineering contribution to this thesis.